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14. ABSTRACT
The goal of this research was to determine how patient safety and the avoidance of medical error can be effectively taught to student nurses in a simulated setting. Three strategies were compared: a) high fidelity (mannequin) b) standardized patient (actor) and c) video platform (virtual). Both the subjects and the research assistants were blinded to the Dependent Variable; the commission of error. Subjects were randomized to each of the three experiments in a crossover design. In each of the four semesters of the study, one group served as a control and were randomized to a one-time experiment, each semester offered one of the three experiments as the control. During the last and fourth semester, all subjects were offered. Medical error was embedded in each of the three experiments.

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INTRODUCTION

The goal of this research was to determine how patient safety and the avoidance of medical error can be effectively taught to student nurses in a simulated setting. Three strategies were compared: a) high fidelity (mannequin) b) standardized patient (actor) and c) video platform (virtual). Both the subjects and the research assistants were blinded to the Dependent Variable: the commission of an error. Subjects were randomized to each of the three experiments in a crossover design. In each of the four semesters of the study, one group served as a control and were randomized to a one-time experiment, each semester offered one of the three experiments as the control. During the last and fourth semester, all subjects were randomized to a one time-experiment and all three experiments were offered. Medical error was embedded in each of the three experiments; the scenarios included distraction.

BODY

Senior nursing students in their final semester were recruited to participate during their "capstone" semester. As one of the largest schools of nursing in the state, we had access to over 200 senior students. The students were asked to participate by faculty who attended a class with the permission of their instructor to brief the students on the time commitment, logistics and provided them with a written consent to participate. Of the students who were asked to participate, **54** participated (80% female, 20% male) over the four semester timeframe. The ages of the participants ranged from 20-30 (mean SD of 25 years). Of the students who actually participated 50% had experienced 25% of the

clinical hours in simulation as a student and 50% had experienced 25% of the clinical hours in only two (2) clinical rotations (pediatrics and obstetrics)

Once consented, subjects arrived to the lab with no prior knowledge of the experiment. The lab was designed to keep the subjects separate utilizing a construction method with exterior halls and soundproofed simulation rooms. Each subject spent up to 15 minutes on the pretest. 15 minutes in the experiment and up to 15 minutes for the post test.

Subjects were randomized to all three experiments in a crossover design with a one month "washout". A consensus of experts agreed on a one-month washout based on prior experience with teaching/learning strategies. Each of the four semesters included one cohort of subjects who were only tested one time in a controlled experiment. The controls were each of the three simulation strategies and the first cohort received a one-time experience in one of the three experiments.

Research Objective #1: To determine if one of three methods or a combination of simulation instruction provides greater mastery in patient safety instruction for pre licensure students.

Initial analysis showed that there was no discernible difference in performance across semesters. To allow for more statistically meaningful analysis, groups were aggregated across semesters (Summer 2012, Fall 2012, Spring 2013) based on treatment order. **Table 1** shows the treatment order for each group. **Table 2** shows the results for the average score on the evaluation form (or virtual reality platform) and sample size n; the percent that committed medical error; and the percent that were distracted from their task; and the weighted average for each treatment number across treatment types. There

were no distractions for the virtual reality treatment.

Table 1: Treatment order for each group

Group	1st Treatment	2nd Treatment	3rd Treatment
A (control group)			
B	Standardized patient	Virtual reality	High fidelity
C	Virtual reality	High fidelity	Standardized patient
D	High fidelity	Standardized patient	Virtual reality

Table 2: Results for each group and each treatment, in chronological order

Group	Treatment 1			Treatment 2			Treatment 3		
	Avg % Score (n)	% Med Error	% Distracted	Avg % Score (n)	% Med Error	% Distracted	Avg % Score (n)	% Med Error	% Distracted
B	50% (8)	38%	0%	80% (3)	0%	n/a	70% (5)	40%	0%
C	68% (10)	9%	n/a	33% (6)	83%	17%	61% (9)	33%	33%
D	44% (8)	38%	50%	50% (5)	60%	40%	73% (6)	17%	n/a
Overall	55% (26)	26%	25%	49% (14)	57%	27%	67% (20)	30%	21%

There appears to be either no change or an improvement in participant score between treatments 1 and 3; however, there may be an increase in medical error. There is not enough evidence to conclude there is a statistically significant difference overall. The largest apparent difference, between Group D's first and third treatment scores, falls short at the $\alpha = 0.05$ level (one-tailed $p = 0.08$). We will use the $\alpha = 0.05$ significance level throughout this report unless otherwise noted.

Research Objective #2: To determine if the sequence of three methods of simulation instruction predicts mastery of patient safety instruction for pre-licensure students.

Table 3 shows the results for each group and each treatment, sorted by treatment.

Table 3: Results for each group and each treatment, grouped by treatment

Group	Standardized Patient			Virtual Reality			High Fidelity		
	Avg % Score (n)	% Med Error	% Distracted	Avg % Score (n)	% Med Error	% Distracted	Avg % Score (n)	% Med Error	% Distracted
B	50% (8)	38%	0%	80% (3)	0%		70% (5)	40%	0%
C	61% (9)	33%	33%	68% (10)	9%		33% (6)	83%	17%
D	50% (5)	60%	40%	73% (6)	17%		44% (8)	38%	50%
Overall	55% (22)	41%	23%	71% (19)	10%		47% (19)	53%	26%

The largest difference in average score is between high fidelity and virtual reality. The hypothesis that the average score for virtual reality ≥ average score for high fidelity is statistically significance with the one-tailed $p = 0.026$.

Medical error appears to be more common in the standardized patient and high fidelity environments than in the virtual reality environment. Both the difference between virtual reality and standardized patient; and between virtual reality and high fidelity are statistically significant, two-tailed $p = 0.03$ and 0.004, respectively.

Because participant results for specific treatments are being combined across treatment numbers, the comparisons above may be obscuring actual differences, or conflating them with other factors. We next examine the differences in treatments using the control groups and only observations from the first treatment for each group.

Table 4 summarizes the results for all participants, including control groups, being exposed to a treatment for the first time, across all semesters.

Table 4: Results for each treatment across control groups and first treatments for all groups, across all semesters.

	Standardized Patient			Virtual Reality			High Fidelity		
	Avg % Score (n)	% Med Error	% Distracted	Avg % Score (n)	% Med Error	% Distracted	Avg % Score (n)	% Med Error	% Distracted
Overall	50% (13)	38%	31%	71% (18)	6%		42% (13)	46%	8%

The results closely mirror those that compared all treatments from Groups B-D. The order in which treatments are administered seems to have less of an impact than the treatment itself.

The difference in average score between virtual reality and high fidelity is statistically significant, two-tailed $p = 0.04$. No other differences in scores are significant ($p = 0.67$ for standardized patient and high fidelity; $p = 0.13$ for standardized patient and virtual reality).

The possible difference in medical error between standardized patient and high fidelity is not statistically significant ($p = 0.71$). The difference in the percent distracted between standardized patient and high fidelity is also not statistically significant ($p = 0.15$).

Overall, 25 instances of medical error occurred across a total 74 observations.

Research Objective #3: To determine if prior exposure during training simulations can predict how students will perform relative to non-participants on a final simulation.

The subjects were chosen from a population of last semester Senior nursing students over a two year period. The first two semester subjects were exposed to 25% of their clinical training hours in simulation across two disciplines (pediatrics and obstetrics). The last two semester subjects were exposed to 25% of their clinical training hours ACROSS their entire curriculum. All subjects are required to take a final comprehensive exam as part of their graduation requirements.

The Health Education System Incorporated (HESI) Summary Reports provide content area scores that can be used to evaluate curricular strengths and weaknesses. Estimated reliability of the HESI demonstrates coefficients (KR-20) of 0.940 (Morrison et al. 2004) Evidence of convergent validity was obtained by comparing HESI exam scores to other measures of the same constructs. In three as-yet unpublished studies, associate degree nursing (ADN) and bachelor of science in nursing (BSN) faculties that use HESI exams provided evidence of convergent validity for these exams by correlating students' HESI exam scores with their final course grades and cumulative grade point averages (GPAs). The correlations were statistically significant ($P < .01$.)

There is no statistically significant difference between HESI scores from Spring 2012 through Summer 2013. The difference in score between the highest and lowest average is 91 points, between the highest and lowest medians is 97 points, on a scale of 0 to 1600.

The following areas (Table 5) had spreads of 150 points or more. It was not possible to conduct significance tests on the individual areas because of lack of standard deviations in the summary data provided.

Table 5 HESI Subcategories

- N1 – Assessment ($\Delta = 178$): max = Sp12, min = Sp13
- N3 – Planning ($\Delta = 155$): max = Su12, min = Sp13
- C1 – Safe Environment ($\Delta = 150$): max = Su12, min = Fa12
- C2 – Management of Care ($\Delta = 170$): max = Su12, min = Sp13
- C3 – Safety and Infection Control: max = Su12, min = Fa12
- C4 – Health Promotion & Maintenance ($\Delta = 149$): max = Su13, min = Sp13
- C10 – Physiological Adaptation ($\Delta = 177$): max = Su13, min = Sp13

Research Objective #4: To design a rubric/model for safety instruction capable of stratifying average and exceptional performance.

We were unable to achieve this objective during the two-year study. We experimented with adapting the Lasater Inventory form (Lasater, 2007) , but this tool depends significantly on the debriefing phase of any given simulation exercise and due to the need to protect the dependent variable, none of our subjects were debriefed (Appendix D). We also experimented with an observational tool (checklist) in which specific tasks were expected and then evaluated. This form served as the basis for one of our evaluation tools, but we did not achieve the statistical power to truly develop this checklist.

KEY RESEARCH ACCOMPLISHMENTS

- Three simulation experiments were compared in classic crossover study. To our knowledge, this has not been done before.
- A video (virtual platform) was developed in which actual actors were filmed to give a more realistic approach to the experiment. Most studies utilize computer-generated avatars that, in this author's opinion, appeal more to the "gaming" aspect of simulation rather than a "reality" approach.
- The Dependent Variable was blinded to both the subjects and the Research Assistants who were themselves chosen across a Liberal Arts campus SPECIFICALLY because they did not have a medical background. We believe this lends more credibility to observation without bias.

REPORTABLE OUTCOMES

- Mid-study report was submitted, accepted and presented to a breakout session audience at the International European Simulation Society (SESAM) in Paris, France, January 2013. Appendix A
- End of study summary was submitted, accepted and presented to a plenary session at the Magic in Teaching conference (Irvine, California October 2013). Appendix B
- A final article is currently under development (first draft Appendix C) for submission to the Simulation in Healthcare journal, an international multi-discipline journal with a high Impact Factor (1.64)
- Results of the study will be more formalized and submitted to the International Medical Simulation in Healthcare (American) conference in 2014.
- Educational strategies developed in this study will be utilized in an Inter professional Education Symposium at the American University, Beirut, Lebanon in June, 2014.

CONCLUSION:

Of the three treatments, the virtual reality scenario had the lowest incidence of medical error, especially compared to the high fidelity simulation. There are two possible explanations for this. The first is that the current generation of students, the Millennials, is very comfortable with and adept at technology, which inherently leads to higher performance. Millennials are defined as those individuals who were born in the time period of the early 1980's to the early 2000's. The second explanation is that the virtual reality simulation requires only ordinary learning, not transference of content and skills (Cook et al, 2012) . In other words, participants in the virtual reality simulation are showing "Understanding" in Bloom's Revised Taxonomy, whereas the other two simulations require "Applying" of knowledge and skills.

Given the limited sample sizes, it is not possible to draw strong conclusions about the efficacy of high fidelity versus standardized patients. Standardized patient scores and medical error rates are higher than those for high fidelity, but the percent distracted are lower.

We argue that virtual reality simulations would be a good tool during earlier education stages, as students are learning fundamental concepts. After they have achieved understanding and are able to recognize good practice, high fidelity or standardized patient simulations can be employed to assist in knowledge and skill transference and assessment.

With respect to the efficacy of ordering of treatments it is not possible to discern any effects of the ordering of treatments. It may be that sample sizes are too small or that the ordering of treatments is less important than the actual type of treatment.

Several limitation and challenges were encountered during this study. Due to the student's class schedule, we had several "no-shows" on occasion and even after attempting to contact them to reschedule, we met resistance. The longitudinal design (three experiment times over three months) was on first notion a strong methodology as each subject could serve as their own control, yet the "drop off" rate presented a problem of statistical power.

The goal of this study was to examine the ability to recognize an embedded medication error in three types of simulation. Tables 1 and 2, which organizes the data in terms of the cycle of treatment, yields little to no statistical significance. The data therefore suggest that despite completing a given previous treatment, the nursing students performed equally well in their next treatment in comparison to other students undergoing the same treatment.

Table 3 offers more statistical evidence that virtual platforms produce higher average scores than both high fidelity and standardized patient treatments. With an average score across all three groups of 71%, virtual platforms surpass the average scores of 55% for standardized patient and 47% for high fidelity. Also, medical error seems to be the lowest with virtual platforms with an average rating of 10%, while high fidelity and standardized patient treatments yielded 55% and 47% respectively. In general, these data suggest that for whatever reason, students performed better in a virtual, instead of hands-on, and interpersonal forum.

Table 4 collates the control groups, which were randomized to a single treatment and not asked to return for following treatments, and the first treatments of groups B, C and D. Data show that without any previous exposure and no proceeding exposure to the treatments, students who underwent virtual treatment derived a higher average score than both high fidelity and standardized patient. Virtual treatments also yielded considerably lower medical error percentages. This suggests with the given student demographic, virtual platforms are more conducive for current students than both high fidelity and standardized patient methods.

A reported 44,000 to 98,000 Americans die annually as a result of medical (Benner et al 2002) error. With this knowledge, it is imperative to not only continue the education of health professionals, but to also encourage active, critical discussion of current educational systems in healthcare. It is clear from the data presented in this study that students undergoing what is considered standard nursing education, are presenting low capability in scenarios requiring active application of their knowledge and skills (i.e. Standardized Patient & High Fidelity).

It can be said that today's generation, in general, has a markedly distinct upbringing in the age of technology. Therefore, we can expect students' performances in virtual platforms, as opposed to those requiring active application, to be better. However, healthcare, as also true in the military, is not a business of passiveness, but a business of active practice. So the question must be asked as to how can today's healthcare (or military) educational system confront this issue presented by students of the age of technology. As this study shows, although limited in subjects and therefore conclusions, the use of progressive methods of education, such as high fidelity mannequins and

technology. As this study shows, although limited in subjects and therefore conclusions, the use of progressive methods of education, such as high fidelity mannequins and standardized patients, can be utilized to help reduce medical risk, and improve future healthcare.

Although conclusions point towards virtual/computer based simulation as being the best methodology for medication error recognition, we wonder if the age of the subjects (~20 years) accounts for a greater comfort with technology and we wonder why the standardized patients demonstrated the greatest challenge for this group of subjects. In a careful systematic review and meta-analysis, Smithberger and colleagues (2012) compared technology-enhanced simulation versus other instructional methods; they concluded that standardized patients and real patients had similar effects for all outcomes except process measures of skills. Since the accuracy of appropriate dose and delivery of medication is a complicated skill, one might conclude that our findings are congruent.

Gaba (2012) maintains that we need to mobilize larger resources to provide more definitive answers to the "big questions about simulation" (p.27). We are grateful to the Department of Defense who provided important resources to advance our understanding of how different simulation strategies serve to educate and train novice learners.

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ATTACHMENT A: PRESENTATION – “Comparing Simulation Strategies to Prevent Medical Error in Baccalaureate Nursing Students” to CESAM in Paris 2013

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Comparing Simulation Strategies to Prevent Medical Error in Baccalaureate Nursing Students

SESAM Paris 2013

Judith Lambton, EdD, RN
KT Waxman, DNP, MBA, RN, CNL, CENP
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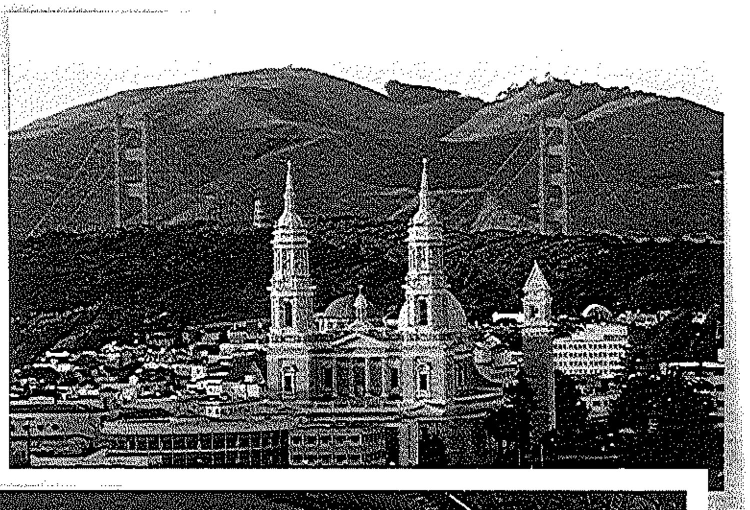
University of San Francisco
San Francisco, California, United States

Disclosures

No disclosures.

University of San Francisco

School of Nursing and Health Professions



- Founded in 1954, USF School of Nursing was the first private university nursing program in California
- In the 1980s, the school began offering graduate degree programs
- In 2007, the school opened the first Doctor of Nursing Practice degree in California
- Launching Master's degree in Clinical Simulation in 2014

Research funded by

TATRC

The United States Department of Defense Telemedicine and Advanced Technology Research Center (TATRC)

Research Goal

To determine how patient safety and the avoidance of medical error can be taught effectively to student nurses in a simulated setting.

A Moral Obligation For Sound Research

Suggested by Ziv who takes the position that patients are “not commodities to be used as conveniences of training.” This research was based on Weinger’s model that guides simulation research based on successful models from pharmacology.

We Compared Three Simulation Strategies

1. Virtual (computer-based)
2. Standardized Patient
3. High-fidelity manikin

On the Ability to Recognize

….medication error embedded into the three simulation exercises.

The medication orders were embedded in a series of “tasks” and “distractions” that included assessment and vital signs.

Subjects were…

Final semester senior nursing students in a Baccalaureate program in San Francisco.

Research assistants were…

Sophomore Baccalaureate students in programs OTHER than Nursing.

Both Subjects and Research Assistants

… were blinded to the Dependent Variable

All Subjects Were Randomized

- To all three experiments in a crossover design with a one month "washout."
- Each semester (4 total) included one cohort of subjects who were only tested one time in a "controlled" experiment; the controls were each of the three simulation strategies and the last cohort received a one-time experience in each of the three experiments.

Comparison of teaching/learning strategies

N=54

Four Semesters (two years)

Results demonstrated that:

- virtual was the most effective
- high-fidelity was 50% effective
- standardized patient was the LEAST effective

Implications

How are we educating our Baccalaureate students at our university?

Should we "start" simulation in Sophomores on a virtual platform?

Should Junior-level; students utilize high-fidelity?

Should Seniors concentrate on standardized patients?

Is Are the "Millennials" different as learners?

Twenge (2006) believes they are more "entitled"

They are certainly more engaged in social media/computer-based platforms

"they would give up their cars before giving up their computers or smartphones"

headline in Atlantic Cities (February, 2013)

KRC Research (December 2012)

Nearly three quarters (73 percent) of Millennials would rather shop online than drive or ride public transit to the store.

Nearly half (47 percent) of Millennials sometimes choose to spend time with friends online instead of driving to see them in person.

Nearly two in three (65 percent) of Millennials say losing their phone (30 percent) or computer (35 percent) would have a greater negative impact on their daily routine than losing their car (28 percent).

How different are they?

Schooley and colleagues (2005) describe millennials as "technology natives" due to their fluency with and early use of technology.

An estimated

- 76.9 percent of people ages 20 to 24 and
- 47.2 percent of those 25 to 29

use social networking several times per week

How to adapt?

The National Association of Colleges and Employers (NACE) and a consortium of organizations on workforce readiness, recently published surveys on what employers seek in college graduates. The results suggest that students need to hone their skills in:

communication

leadership

professionalism

teamwork/collaboration

problem solving, and

critical thinking.

We Will Carry On

Thank you

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ATTACHMENT B: PRESENTATION – "Exploring Simulation Strategies for Best Practice in Teaching Medication Error Recognition" November 2013

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Exploring Simulation Strategies for Best Practice in Teaching Medication Error Recognition

Magic in Teaching, November, 2013

Judith Lambton, EdD, RN

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San Francisco, California

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We Will Carry On

Thank you

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ATTACHMENT C: Best Practices in Simulation

Exploring Simulation Strategies for Best Practice in Teaching Medication Error Recognition

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Abstract

Healthcare simulation education can contribute to students understanding of the significance of patient safety, specifically medication error recognition. To determine how patient safety and the avoidance of medication error can be taught effectively to student nurses in a simulated setting, we designed a study to compare three simulation strategies: virtual (computer-based), standardized patient and a high-fidelity mannequin. Our study examined the ability to recognize an embedded medication error in all three simulation exercises. The data included 55 senior nursing students from a baccalaureate program over four semesters. Results showed that students did best in recognizing medication error with the video platform. There was a correlation between the students who had experienced 25% of their curriculum practice hours in simulation and those who did not. Simulation is an excellent methodology to teach students medication recognition; the exact medium of simulation depends on the age of the students and the types of simulation available in the lab.

Key words: simulation, medication error, high-fidelity, standardized patient, video

Background and Introduction

Administering medications is a complex task. Patients depend upon the knowledge and expertise of those who order medications and those who administer them. Administration of medications in a hospital setting is a daily occurrence; every nurse administers at least one medication for every patient, every day [1].

An Institute of Medicine (IOM) report concluded that at least 1.5 million preventable medication errors occur each year in the United States (not including errors of omission) and on average a hospitalized patient is subjected to more than one medication error each day [1].

Educating nursing students on the importance of safe medication administration before they are employed as staff nurses is imperative and simulation plays a vital role in this education. There is a strong consensus that collaborative practice between physician and nurse should result in a concert of the right patient, drug, dose, route, and time. [3], and documentation. [4] This is not an error proof strategy.

Simulation is an innovative teaching method that is being utilized in healthcare education, and is a proven teaching strategy. Ziv and colleagues [5] suggest that patients are "not commodities to be used as conveniences of training"; clinical educators in both Medicine and Nursing are tasked with developing novel strategies to educate the novice learner while protecting patient safety. While many simulation programs have proliferated across the country and globally, we do not yet fully understand the dose, frequency or appropriate amount of simulation that is appropriate to replace or enhance the traditional model of "guild" learning seen in traditional clinical education.

With the increased sophistication of simulation equipment, and the growth of simulation centers and research programs, curriculum development in simulation-based education has become a priority. Gordon et al [5] suggest that if simulated cases can recreate the cognitive dynamics of real encounters, then important educational moments can be controlled and efficiently replicated in a safe environment.

In current healthcare settings, the opportunity to learn is restricted by: a) the availability of clinical learning opportunity b) the competition among different levels of education (doctors, nurses, paramedics) to learn in situ and c) the financial and emotional cost (both to patient and health care providers) of medical error on the part of novice learners. Patient safety concerns have shaped the way in which students can interact with patients at the bedside, and the way in which educators now view the "clinical learning lab". Ziv et al [4] take the position that the use of simulation, wherever feasible, conveys a critical educational and ethical message to all: patients are to be protected whenever possible and they are not commodities to be used as conveniences of training.

The situation now exists, that it is not if simulated learning is effective, but when to use it, how to do it and how to evaluate its impact. Weinger [6] offers a conceptual framework to guide simulation research by incorporating past successful research models from pharmacology. Recent work by Smithberger et al [7] compared the effectiveness of three learning strategies: simulation-based, problem-based and standardized patients in pharmacy doctoral students; this appears to be one of the first attempts study different educational approaches in a randomized study.

Our study compares one simulation format with another using different levels of fidelity, different combinations of simulation techniques and different instructional techniques as a way to determine "dose-effect," "dose timing" and "drug-drug relationships."

Continuing with the notion of a pharmaceutically-based model, crossover studies achieve clarity as each subject serves as his or her own "control." Nearly all crossover designs have "balance," which means that all subjects should receive the same number of treatments and that all subjects participate for the same number of periods. In most crossover trials, in fact, each subject receives all treatments. Adapting Weinger's model using crossover methodology may inform and guide a research agenda that advances the question: which simulation strategy best achieves a given outcome?

This research attempts to explore patient safety as an outcome (referred to here loosely as the dependent variable) when different simulation strategies (high fidelity, standardized patients and virtual simulation) are presented (independent variable) to the novice learner. Spross and Baggerly [8] have identified key competencies in several domains of healthcare practice. Working within these domains, systematic and human factor errors will be embedded into the case scenarios that are assigned to three possible experimental situations. Errors were chosen to encompass the three major categories of human operator failure as defined by Rasmussen: [10]

a) skill-based errors: errors that occur during "routine" task

b) rule-based error: failure to follow protocol

c) knowledge error: lack of or inappropriate application of knowledge

This Department of Defense (DOD) grant funded study was conducted over four semesters specifically addressing medication error recognition with senior nursing students in a

baccalaureate nursing program at a private university in San Francisco, California. The study was designed to determine how patient safety and the avoidance of medical error can be taught effectively to student nurses in a simulated setting. The study investigated which simulation methodology worked best in medication error recognition: virtual (video platform), high-fidelity simulation (mannequin) or standardized patient (actor).

METHODS

Design

A potential medication error was embedded into each of the three simulation scenarios written by the design team. The content of the scenarios was validated by three (3) experts

The medication orders were embedded in a series of "tasks" and "distractions" that included assessment and vital signs. All subjects were randomized to all three experiments in a crossover design with a one-month "washout." The washout period was determined by the content experts to be sufficient for subjects to "forget" the prior experiment. Each semester (4 total) included one cohort of subjects who were only tested one time in a "controlled" experiment; the controls were each of the three simulation strategies and the last cohort received a one-time experience in each of the three experiments. The study utilized a randomized, crossover double-blind design.

Subjects were consented to the study as "participating in a study comparing simulation strategies"; they did not know the dependent variable (medication error). The Research Assistants (RA) were recruited from a pool of undergraduate students across a liberal arts campus with nursing students excluded in order to achieve a "naïve" pool of RA's. The RA's were oriented to the study design but were not informed of the dependent variable (medication error). None of the faculty investigators participated in the data collection.

Subjects completed a pre test that measured the cognitive domain; the tests were written and validated by three (3) content experts and were tested on the same group of eleven (11) participants prior to beginning the study. Subjects were introduced to each of the three (3) experiments and were given fifteen (15) minutes to complete the assignment. Each simulation was stopped at: a) fifteen minute mark or b) when the student discovered the potential medication error and reported it to someone.

The mannequin (high fidelity) experiment was an adult patient who had undergone abdominal surgery and was complaining of pain and hunger. The medication order was for 100 mg of Lasix IVP; which exceeded the appropriate dose. A telephone was available to call the physician.

The Standardized Patient (SP) experiment included an actor who had a long-standing history of asthma and had multiple complaints throughout the time period. Prednisone was ordered, but the patient stated that he "could not swallow pills". A pill crusher was available in the patient's medication tray along with the Prednisone tablets. A syrup of Prednisolone was also available. The subjects were to decide which medication was appropriate. A telephone was available to call the physician. Both the high-fidelity and standardized patient experiments were videotaped.

The virtual (computer-based) simulation was designed by three content experts and consisted of a videotaped sequence in which the subjects were required to then make a "correct" choice of one of three videotaped approaches. The virtual platform was housed on a Blackboard ™ site, one that each student had familiarity and login access. There were five video-questions; the answers could be accessed by the faculty investigators.

Participants were classified as to whether they: a) committed a medical error and b) whether they were distracted from the important task they were to complete. Medical error was defined as the wrong dose, the wrong medication, inappropriate protocol or being distracted during the allotted time.

Evaluation tools

Materials

Several evaluation instruments were used in study and included:

a) a ten question pre/post exam (cognitive measure)

b) A self report of satisfaction

c) Performance Checklist (direct observation)

d) The Health Education Systems, Incorporated (HESI) (a pre-board exam)

The knowledge pretest was administered when the subject arrived at the laboratory for their study experience and immediately after the simulation. The 10-item pre and posttest was piloted with one summer group of senior students prior to the beginning of the study. The test showed some issues with repetitive questions and was manipulated from a 13 questions test to a 10 question test. Every semester showed a strong, consistent item analysis (point-Bi-serial).

The satisfaction survey was given to the participants after all three simulation variations were completed by the student at the end of their study experience. This 29 item survey allowed the participant to self-report on their overall learning effectiveness of the simulation experiences and self-confidence in error recognition and treatment.

To assist the observers who viewed the participant's video performance, a key competencies checklist was developed by two clinical experts who study medication errors. The sequential checklist was evaluated for satisfactory content validity by 3 experts.

The HESI Summary Reports provide content area scores that can be used to evaluate curricular strengths and weaknesses. Estimated reliability of the HESI demonstrates coefficients (KR-20) of 0.940. Evidence of convergent validity was obtained by comparing HESI exam scores to other measures of the same constructs. In three as-yet unpublished studies, associate degree nursing (ADN) and bachelor of science in nursing (BSN) faculties that use HESI exams provided evidence of convergent validity for these exams by correlating students' HESI exam scores with their final course grades and cumulative grade point averages (GPAs). The correlations were statistically significant ($P < .01$.) [11]

This study compared the HESI exam scores for subjects and non-participants in all four semesters and compared the grade point average (GPA) of the study subjects and a select group (consented) of non-participants.

Participants/Subject recruitment

Senior nursing students in their final semester were recruited to participate during their "capstone" semester. As one of the largest schools of nursing in the state, we had access to over 200 senior students. The students were asked to participate by faculty who attended a class with the permission of their instructor to brief the students on the time commitment, logistics and provided them with a written consent to participate. Of the students who were asked to participate, 54 participated (80% female, 20% male) over the four semester timeframe. The ages of the participants ranged from 20-30 (mean SD of 25 years). Of the students who actually participated 50% had experienced 25% of the clinical hours in simulation as a student and 50% had experienced 25% of the clinical hours in only two (2) clinical rotations (pediatrics and obstetrics)

Institutional Review Board

An application for protection of human subjects was submitted to both the university in which the subjects were students and the Department of Defense, the organization that funded this study. Both Institutional Review Boards gave permission to conduct the study. All of the subjects were consented using the term "this study is set to compare here different simulation teaching strategies". Thus, the dependent variable (medication error) was not revealed.

Methodology

Once consented, subjects arrived to the lab with no prior knowledge of the experiment. The lab was designed to keep the subjects separate utilizing a construction method with exterior halls and soundproofed simulation rooms Each subject spent up to 15 minutes on the pretest. 15 minutes in the experiment and up to 15 minutes for the post test.

Subjects were randomized to all three experiments in a crossover design with a one month "washout". A consensus of experts agreed on a one-month washout based on prior experience. Each of the four semesters included one cohort of subjects who were only tested one time in a controlled experiment. The controls were each of the three simulation strategies and the first cohort received a one-time experience in one of the three experiments.

Results

Initial analysis showed that there was no discernible difference in performance across semesters. To allow for more statistically meaningful analysis, groups were aggregated across semesters (Summer 2012, Fall 2012, Spring 2013) based on treatment order. Table 1 shows the treatment order for each group. Table 2 shows the results for the average score on the evaluation form (or virtual reality platform) and sample size n; the percent that committed medical error; and the percent that were distracted from their task; and the weighted average for each treatment number across treatment types. There were no distractions for the virtual reality treatment.

Table 1: Treatment order for each group

Group	1st Treatment	2nd Treatment	3rd Treatment
A (control group)			
B	Standardized patient	Virtual reality	High fidelity
C	Virtual reality	High fidelity	Standardized patient
D	High fidelity	Standardized patient	Virtual reality

Table 2: Results for each group and each treatment, in chronological order

Group	Treatment 1			Treatment 2			Treatment 3		
	Avg % Score (n)	% Med Error	% Distracted	Avg % Score (n)	% Med Error	% Distracted	Avg % Score (n)	% Med Error	% Distracted
B	50% (8)	38%	0%	80% (3)	0%	n/a	70% (5)	40%	0%
C	68% (10)	9%	n/a	33% (6)	83%	17%	61% (9)	33%	33%
D	44% (8)	38%	50%	50% (5)	60%	40%	73% (6)	17%	n/a
Overall	55% (26)	26%	25%	49% (14)	57%	27%	67% (20)	30%	21%

Despite aggregation, Treatment 2 has fairly small sample sizes, making it difficult to draw conclusions; the relatively small samples make drawing strong conclusions inadvisable.

There appears to be either no change or an improvement in participant score between treatments 1 and 3; however, there may be an increase in medical error. There is not enough evidence to conclude there is a statistically significant difference overall. The largest apparent difference, between Group D's first and third treatment scores, falls short at the $\alpha = 0.05$ level (one-tailed $p = 0.08$). We will use the $\alpha = 0.05$ significance level throughout this paper unless otherwise noted.

Table 3 shows the results for each group and each treatment, sorted by treatment.

Table 3: Results for each group and each treatment, grouped by treatment

Group	Standardized Patient			Virtual Reality			High Fidelity		
	Avg % Score (n)	% Med Error	% Distracted	Avg % Score (n)	% Med Error	% Distracted	Avg % Score (n)	% Med Error	% Distracted
B	50% (8)	38%	0%	80% (3)	0%		70% (5)	40%	0%
C	61% (9)	33%	33%	68% (10)	9%		33% (6)	83%	17%
D	50% (5)	60%	40%	73% (6)	17%		44% (8)	38%	50%
Overall	55% (22)	41%	23%	71% (19)	10%		47% (19)	53%	26%

The largest difference in average score is between high fidelity and virtual reality. The hypothesis that the average score for virtual reality ≥ average score for high fidelity is statistically significance with the one-tailed $p = 0.026$.

Medical error appears to be more common in the standardized patient and high fidelity environments than in the virtual reality environment. Both the difference between virtual reality and standardized patient; and between virtual reality and high fidelity are statistically significant, two-tailed $p = 0.03$ and 0.004, respectively.

Because participant results for specific treatments are being combined across treatment numbers, the comparisons above may be obscuring actual differences, or conflating them with other factors. We next examine the differences in treatments using the control groups and only observations from the first treatment for each group.

Table 4 summarizes the results for all participants, including control groups, being exposed to a treatment for the first time, across all semesters.

Table 4: Results for each treatment across control groups and first treatments for all groups, across all semesters.

	Standardized Patient			**Virtual Reality**			**High Fidelity**		
	Avg % Score (n)	% Med Error	% Distracted	Avg % Score (n)	% Med Error	% Distracted	Avg % Score (n)	% Med Error	% Distracted
Overall	50% (13)	38%	31%	71% (18)	6%		42% (13)	46%	8%

The results closely mirror those in Table 3, which compare all treatments from Groups B-D. The order in which treatments are administered seems to have less of an impact than the treatment itself.

The difference in average score between virtual reality and high fidelity is statistically significant, two-tailed $p = 0.04$. No other differences in scores are significant ($p = 0.67$ for standardized patient and high fidelity; $p = 0.13$ for standardized patient and virtual reality).

The possible difference in medical error between standardized patient and high fidelity is not statistically significant ($p = 0.71$). The difference in the percent distracted between standardized patient and high fidelity is also not statistically significant ($p = 0.15$).

Overall, 25 instances of medical error occurred across a total 74 observations.

HESI

There is no statistically significant difference between HESI scores from Spring 2012 through Summer 2013. The difference in score between the highest and lowest average is 91 points, between the highest and lowest medians is 97 points, on a scale of 0 to 1600.

The following areas had spreads of 150 points or more. It was not possible to conduct significance tests on the individual areas because of lack of standard deviations in the summary data provided.

- N1 – Assessment ($\Delta = 178$): max = Sp12, min = Sp13
- N3 – Planning ($\Delta = 155$): max = Su12, min = Sp13
- C1 – Safe Environment ($\Delta = 150$): max = Su12, min = Fa12
- C2 – Management of Care ($\Delta = 170$): max = Su12, min = Sp13
- C3 – Safety and Infection Control: max = Su12, min = Fa12
- C4 – Health Promotion & Maintenance ($\Delta = 149$): max = Su13, min = Sp13
- C10 – Physio Adaptation ($\Delta = 177$): max = Su13, min = Sp13

Efficacy of treatment type

Of the three treatments, the virtual reality scenario had the lowest incidence of medical error, especially compared to the high fidelity simulation. There are two possible explanations for this. The first is that the current generation of students, the Millennials, is very comfortable

with and adept at technology, which inherently leads to higher performance. Millennials are defined as those individuals who were born in the time period of the early 1980's to the early 2000's. The second explanation is that the virtual reality simulation requires only ordinary learning, not transference of content and skills [12, 13] ;. In other words, participants in the virtual reality simulation are showing "Understanding" in Bloom's Revised Taxonomy, whereas the other two simulations require "Applying" of knowledge and skills [14]

Given the limited sample sizes, it is not possible to draw strong conclusions about the efficacy of high fidelity versus standardized patients. Standardized patient scores and medical error rates are higher than those for high fidelity, but the percent distracted are lower.

We argue that virtual reality simulations would be a good tool during earlier education stages, as students are learning fundamental concepts. After they have achieved understanding and are able to recognize good practice, high fidelity or standardized patient simulations can be employed to assist in knowledge and skill transference and assessment.

Efficacy of ordering of treatments

As outlined in Sections x and y, it is not possible to discern any effects of the ordering of treatments. It may be that sample sizes are too small or that the ordering of treatments is less important than the actual type of treatment, as discussed in the previous section.

Limitations/Challenges

Several challenges were encountered during this study. Due to the student's class schedule, we had no-shows on occasion and even after attempting to contact them to reschedule, we met resistance. The . longitudinal design (three experiment times) was on first notion a strong design as each subject could serve as their own control, the "drop off" rate presented a problem of statistical power.

Discussion

The goal of this study was to examine the ability to recognize an embedded medication error in three types of simulation.

Tables 1 and 2, which organizes the data in terms of the cycle of treatment, yields little to no statistical significance. The data therefore suggests that despite completing a given previous treatment, the nursing students performed equally well in their next treatment in comparison to other students undergoing the same treatment.

Table 3 offers more statistical evidence that virtual platforms produce higher average scores than both high fidelity and standardized patient treatments. With an average score across all three groups of 71%, virtual platforms surpass the average scores of 55% for standardized patient and 47% for high fidelity. Also, medical error seems to be the lowest with virtual platforms with an average rating of 10%, while high fidelity and standardized patient treatments yielded 55% and 47% respectively. In general, this data suggests that for whatever reason, students performed better in a virtual, instead of hands-on, and interpersonal forum.

Table 4 collates the control groups, which were randomized to a single treatment and not asked to return for following treatments, and the first treatments of groups B, C and D. Data shows that without any previous exposure and no proceeding exposure to the treatments, students who underwent virtual treatment derived a higher average score than both high fidelity and standardized patient. Virtual treatments also yielded considerably lower medical error percentages. This suggests with the given student demographic, virtual platforms are more conducive for current students than both high fidelity and standardized patient methods.

A reported 44,000 to 98,000 Americans die annually as a result of medical error [2] With this knowledge, it's imperative to not only continue the education of health professionals, but to

also encourage active, critical discussion of today's educational systems in healthcare. It is clear from the data presented in this study that students undergoing what is considered standard nursing education, are presenting low capability in scenarios requiring active application of their knowledge and skills (i.e. Standardized Patient & High Fidelity).

It can be said that today's generation, in general, has a markedly distinct upbringing in the age of technology. Therefore, we can expect students' performances in virtual platforms, as opposed to those requiring active application, to be better. However, healthcare is not a business of passiveness, but a business of active practice. So the question must be asked as to how can today's healthcare educational system confront this issue presented by students of the age of technology. As this study shows, although limited in subjects and therefore conclusions, the use of progressive methods of education, such as high fidelity mannequins, can be utilized to help reduce medical risk, and improve future healthcare.

Conclusions

Although conclusions point towards virtual/computer based simulation as being the best methodology for medication error recognition, we wonder if the age of the subjects (~20 years) accounts for a greater comfort with technology and we wonder why the standardized patients demonstrated the greatest challenge for this group of subjects. In a careful systematic review and meta-analysis [15] compared technology-enhanced simulation versus other instructional methods; they concluded that standardized patients and real patients had similar effects for all outcomes except process measures of skills. Since the accuracy of appropriate dose and delivery of medication is a complicated skill, one might conclude that our findings are congruent.

Gaba [16] maintains that we need to mobilize larger resources to provide more definitive answers to the "big questions about simulation" (p.27). We are grateful to the Department of

Defense who provided important resources to advance our understanding of how different simulation strategies serve to educate and train novice learners.

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ATTACHMENT D: Global Assessment of Student Performance–

Lasater Clinical Judgement Rubric

Lasater Clinical Judgment Rubric[1]

This form is a global assessment of student performance with one of the simulation formats. Please rate each student in each dimension according to their demonstrated competency.

Dimension	Exemplary=4	Accomplished=3	Developing=2	Beginning=1	Observer rating
Effective noticing involved:					
Focused observation	Focuses observation appropriately; regularly observes and monitors a wide variety of objective and subjective data to uncover any useful information	Regularly observes and monitors a variety of data, including both subjective and objective; most useful information is noticed; may miss the most subtle signs	Attempts to monitor a variety of subjective and objective data but is overwhelmed by the array of data; focuses on the most obvious data, missing some important information	Confused by the clinical situation and the amount and kind of data; observation is not organized and important data are missed, and/or assessment errors are made	
Recognizing deviations from expected patterns	Recognizes subtle patterns and deviations from expected patterns in data and uses these to guide the assessment	Recognizes most obvious patterns and deviations in data and uses these to continually assess	Identifies obvious patterns and deviations, missing some important information; unsure how to continue the assessment	Focuses on one thing at a time and misses most patterns and deviations from expectations; misses opportunities to refine the assessment	
Information seeking	Assertively seeks information to plan intervention: carefully collects useful subjective data from observing and interacting with the patient and family	Actively seeks subjective information about the patient's situation from the patient and family to support planning interventions; occasionally does not pursue important leads	Makes limited efforts to seek additional information from the patient and family; often seems not to know what information to seek and/or pursues unrelated information	Is ineffective in seeking information; relies mostly on objective data; has difficulty interacting with the patient and family and fails to collect important subjective data	
Effective interpreting involves:					
Prioritizing data	Focuses on the most relevant and important data useful for explaining the patient's condition	Generally focuses on the most important data and seeks further relevant information but also may try to attend to less pertinent data	Makes an effort to prioritize data and focus on the most important, but also attends to less relevant or useful data	Has difficulty focusing and appears not to know which data are most important to the diagnosis; attempts to attend to all available data	
Making sense of data	Even when facing complex, conflicting, or confusing data, is able to (a) note and make sense of patterns in the patient's data, (b) compare these with known patterns (from the nursing knowledge base, research, personal experience, and intuition), and (c) develop plans for interventions that can be justified in terms of their likelihood of success	In most situations, interprets the patient's data patterns and compares with known patterns to develop an intervention plan and accompanying rationale; the exceptions are rare or in complicated cases where it is appropriate to seek the guidance of a specialist or a more experienced nurse	In simple, common, or familiar situations, is able to compare the patient's data patterns with those known and to develop or explain intervention plans; has difficulty, however, with even moderately difficult data or situations that are within the expectations of students; inappropriately requires advice or assistance	Even in simple, common, or familiar situations, has difficulty interpreting or making sense of data; has trouble distinguishing among competing explanations and appropriate interventions, requiring assistance both in diagnosing the problem and developing an intervention	

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Effective responding involves					
Dimension	**Exemplary=4**	**Accomplished=3**	**Developing=2**	**Beginning=1**	**Rating**
Calm, confident manner	Assumes responsibility; delegates team assignments; assesses patients and reassures them and their families	Generally displays leadership and confidence and is able to control or calm most situations; may show stress in particularly difficult or complex situations	Is tentative in the leader role; reassures patients and families in routine and relatively simple situations, but becomes stressed and disorganized easily	Except in simple and routine situations, is stressed and disorganized, lacks control, makes patients and families anxious or less able to cooperate	
Clear communica tion	Communicates effectively; explains interventions; calms and reassures patients and families; directs and involves team members, explaining and giving directions; checks for understanding	Generally communicates well; explains carefully to patients; gives clear directions to team; could be more effective in establishing rapport	Shows some communication ability (e.g., giving directions); communication with patients, families, and team members is only partly successful; displays caring but not competence	Has difficulty communicating; explanations are confusing; directions are unclear or contradictory; patients and families are made confused or anxious and are not reassured	
Well-planned intervention - flexibility	Interventions are tailored for the individual patient; monitors patient progress closely and is able to adjust treatment as indicated by patient response	Develops interventions on the basis of relevant patient data; monitors progress regularly but does not expect to have to change treatments	Develops interventions on the basis of the most obvious data; monitors progress but is unable to make adjustments as indicated by the patient's response	Focuses on developing a single intervention, addressing a likely solution, but it may be vague, confusing, and/or incomplete; some monitoring may occur	
Being skillful	Shows mastery of necessary nursing skills	Displays proficiency in the use of most nursing skills; could improve speed or accuracy	Is hesitant or ineffective in using nursing skills	Is unable to select and/ or perform nursing skills	
Effective reflecting involves					
Evaluation, self-analysis	Independently evaluates and analyzes personal clinical performance, noting decision points, elaborating alternatives, and accurately evaluating choices against alternatives	Evaluates and analyzes personal clinical performance with minimal prompting, primarily about major events or decisions; key decision points are identified, and alternatives are considered	Even when prompted, briefly verbalizes the most obvious evaluations; has difficulty imagining alternative choices; is self-protective in evaluating personal choices	Even prompted evaluations are brief, cursory, and not used to improve performance; justifies personal decisions and choices without evaluating them	
Commitment to improvement	Demonstrates commitment to ongoing improvement; reflects on and critically evaluates nursing experiences; accurately identifies strengths and weaknesses and develops specific plans to eliminate weaknesses	Demonstrates a desire to improve nursing performance; reflects on and evaluates experiences; identifies strengths and weaknesses; could be more systematic in evaluating weaknesses	Demonstrates awareness of the need for ongoing improvement and makes some effort to learn from experience and improve performance but tends to state the obvious and needs external evaluation	Appears uninterested in improving performance or is unable to do so; rarely reflects; is uncritical of himself or herself or overly critical (given level of development); is unable to see flaws or need for improvement	
				Overall rating (sum of all the dimension scores)	

Additional observer comments: